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Australites from four localities in the Eastern Goldfields, Western Australia

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Abstract

Four samples of australites from the Eastern Goldfields of Western Australia containing 244-616 specimens each have been examined. Specific gravity frequencies are those of the "normal australite" chemical type. Most differences in morphology between the samples can be understood in terms of distance from the salt lakes and degrees of exposure to weathering and erosion. Mean weights of whole specimens in the four locality samples increase irregularly from 1.62 g in a sample with the number of cores to lens-forms in the ratio 0.18 to 3.67 g in a sample with ratio 0.89. It is concluded tentatively that there was little initial variation in the morphology of the australites from place to place in the Eastern Goldfields except in those features such as percentages of cores and lens-forms, which are size-dependent.

Introduction

Australites (Australian tektites) have been found abundantly at numerous localities in the southern half of Western Australia, but collections contain few representative locality samples. A thoroughly representative sample requires the recovery of all possible australites from the area, including the smallest ones and fragments. If the sample is to be classified in some system which has many categories, it also needs to be sufficiently numerous for the less common types to be correctly represented. The four samples examined in this study contain only 244-616 specimens each. However, all samples are from the private collections of Mr and Mrs R G Tillotson and Mr and Mrs L D Tillotson of Kalgoorlie, and thus have been gathered by unusually thorough and acute observers. The large size of the Tillotson collections (c 11 000 australites) is an indication of that acuity of observation. A few australites from the four localities held in other collections were also examined but are not included in the statistics of the samples.

Samples 1-4 were found in the Eastern Goldfields within the semi-arid interior of Western Australia (Fig. 1). Mean rainfall is less than 250 mm/a. Drainage is internal to salt lakes which rapidly evaporate to dryness, their usual condition. Australites are found in this region on the surface of the ground or partly embedded in surficial materials. Australites are moved towards the salt lakes by soil creep processes and rain wash. They are thus found especially on the low-lying approaches to the lakes, in the beds of ephemeral rain-wash streams, on the flat alluvial fans at the lake edges, and elsewhere along the margins of the lakes.

Each of the Samples 1-4 was classified morphologically. Detailed statements are not presented, but extracts from the classifications are shown in Table 1, columns 1-4 respectively. The classification and extracts follow the system and methods of Cleverly (1986).

The Eastern Goldfields are central to a large area comprising the southern half of Western Australia and immediately adjacent part of South Australia in which australites belong to the "normal" chemical type of Chapman (1971, Fig. 2). The frequency diagram of specific gravity for the normal type has a single mode in the 2.44-2.46 interval and no values >2.47 (Chapman 1971). Analyses of australites from the "normal australite" region with specific gravity and refractive index data are given by Mason (1979, Table 1. analyses 1-13).

Location and description of Samples 1-4

Sample 1 Goongarrie Mining Centre is 82 km NNW of Kalgoorlie (Fig. 1). The nearby Lake Goongarrie is usually dry and wind-swept, there being no surrounding high ground to afford protection. The australite sample of 379 specimens was gathered from the gently sloping western

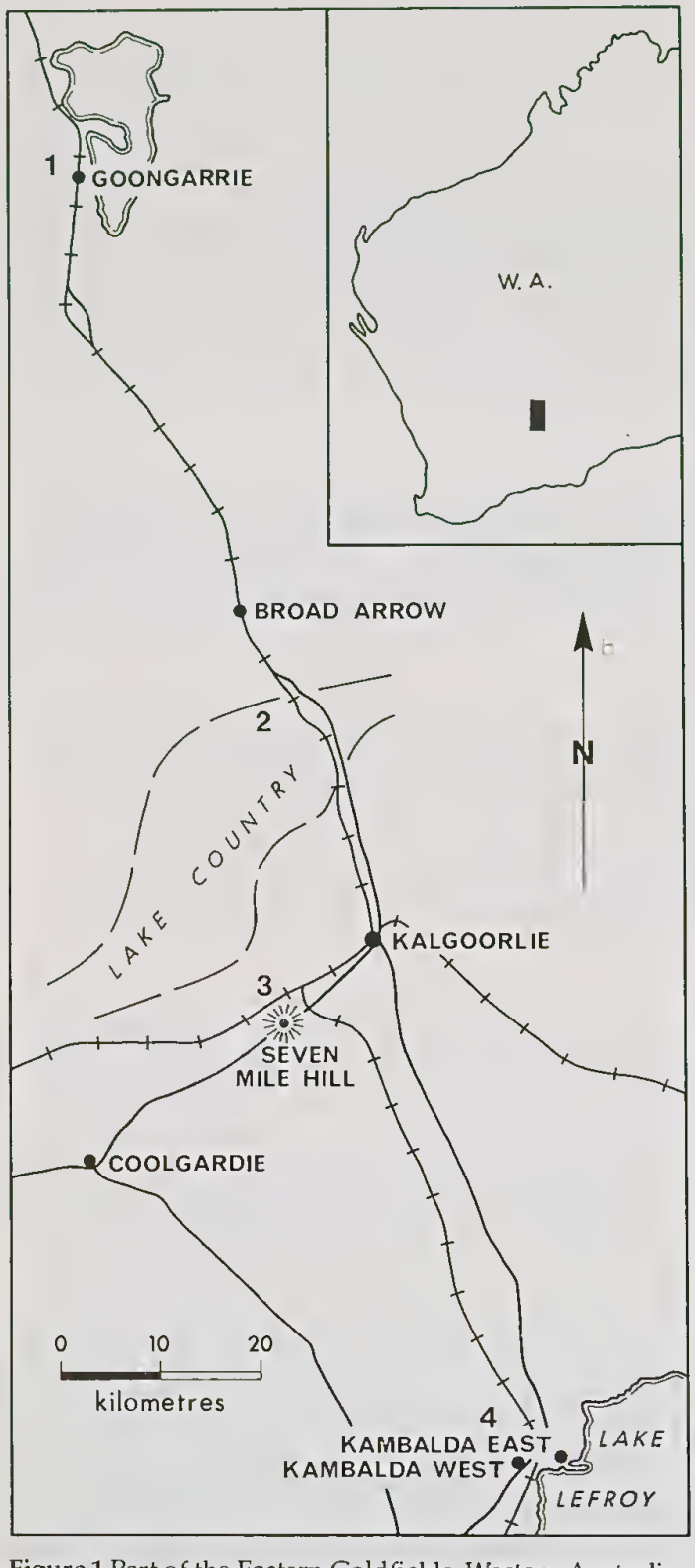

Figure 1 Part of the Eastern Goldfields, Western Australia, showing find sites of australite samples 1-4. Inset: Western Australia showing location of map area.

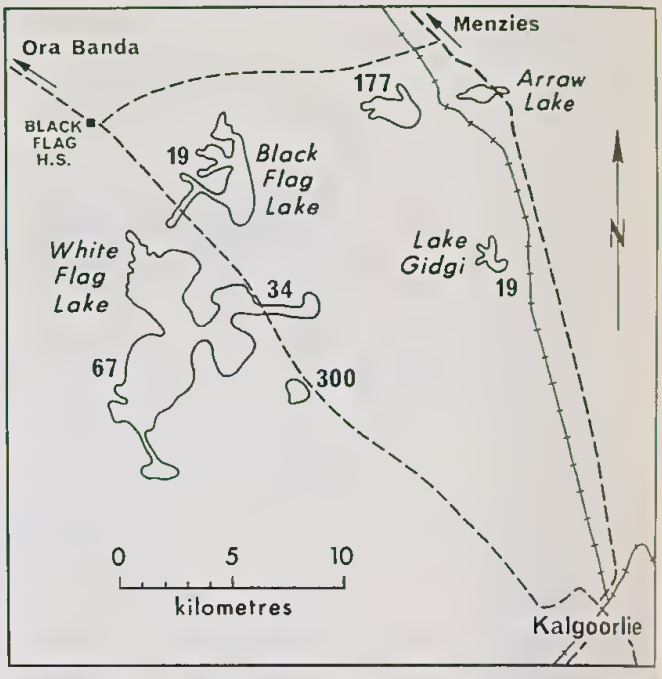

Figure 2 Country north-west of Kalgoorlie, Western Australia, showing localities and numbers of australites constituting the sample from the lake country. Only pertinent lakes are shown.

approaches to the southern half of the lake and the adjoining western portion of the lake.

Most australites from this area are severely abraded (Fig. 5A), though not to the extreme pebble shapes shown by those from Lake Wilson, South Australia, where australites now show no evidence of flanges or flow ridges (Chapman 1964).

Cores in the Goongarrie sample have well rounded elevational profiles rather than defined rims (Fig. 5B). Worn flow ridges are sometimes recognisable (Fig. 5C), but well preserved flow ridges or other indications of flight orientation are unusual (Fig. 5D). Thus, although a lens-form may be recognised by its cross section, its flight orientation is generally indeterminate. Australites with V-grooves (Fig. 5E) or other evidence of chemical etching are also unusual.

The sample contains only 10 shape types (Table 1, item 1). With the exception of a few stout aberrant forms, the identifiable fraction consists of lens-forms and cores (items 15 and 17), the ultimate identifiable survivors of smaller and larger primary bodies respectively. Flanged forms, indicators and fragile forms have been converted to more stable end shapes or rendered unrecognisable in the severely abrasive conditions near the margin of the lake. The abraded state of this sample is reflected also in the unusually low 28.5% of identifiable specimens (Table 1, items 2, 3 and 6). Abrasion—rather than derivation from primarily round bodies—is the likely reason for the exceptionally high 85.4% of round forms (item 7). In contrast, the mean percentage and standard deviation for round forms in five other samples from the Eastern Goldfields (Cleverly 1986, 1988a, samples 2-4 of this paper) are 64.4±3.2%.

The specific gravities of 333 specimens from Goongarrie in the Tillotson collections were determined by Chapman (1971, Fig. 4(d)). The figure illustrates typical "normal australites and normal philippinites" in Chapman's chemical classification.

Table 1

Comparison between australite samples from 1 Goongarrie 2 Lake country NW of Kalgoorlie 3 Seven Mile Hill 4 Vicinity of Kambalda

		1	2	3	4
1	Number of shape types in sample	10	15	21	18
2	Complete forms or essentially so %	18.2	34.4	39.1	50.4
3	Incomplete but classifiable %	10.3	15.9	14.7	11.5
4	Unclassifiable, largely abraded or fragments %	70.7	49.2	45.8	38.1
5	Flakes and flaked cores %	0.8	0.5	0.3	-
6	Total classifiable %	28.5	50.3	53.8	61.9
7	Round forms %	85.4	68.5	64.5	63.3
8	Broad oval forms %	1.0	7.9	9.7	9.5
9	Narrow oval forms %	3.9	7.2	6.5	10.2
10	Boat forms %	4.8	4.6	5.2	5.4
11	Dumbbell forms %	3.9	7.2	8.9	7.5
12	Teardrop forms %	1.0	4.6	5.2	4.1
13	Flanged, disc and plate, bowl and canoe forms %	-	-	7.1	1.4
14	Indicators I %	-	0.7	3.9	2.7
15	Lens-forms %	64.1	75.6	74.9	49.7
16	Indicators II %	-	0.7	0.6	2.0
17	Cores %	35.9	23.0	13.5	44.2
18	Total fragile forms and indicators %	-	1.4	11.6	6.1
19	Cores/lens forms	0.56	0.30	0.18	0.89
20	Number of essentially complete forms	69	212	117	123
21	Mean weight of above (g)	1.93	1.71	1.62	3.67
22	Total number of specimens in sample	379	616	299	244
23	Mean weight of all specimens (g)	1.37	1.21	1.24	2.53

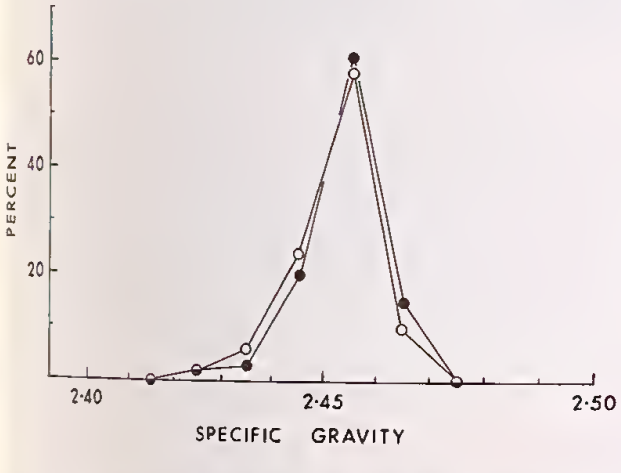

Figure 3 Frequency diagrams of specific gravity for australites. Open circle: sample of 50 australites from lake country north-west of Kalgoorlie. Filled circles: sample of 59 australites from Gindalbie and Broad Arrow from Chapman *et al* (1964, Fig. 3).

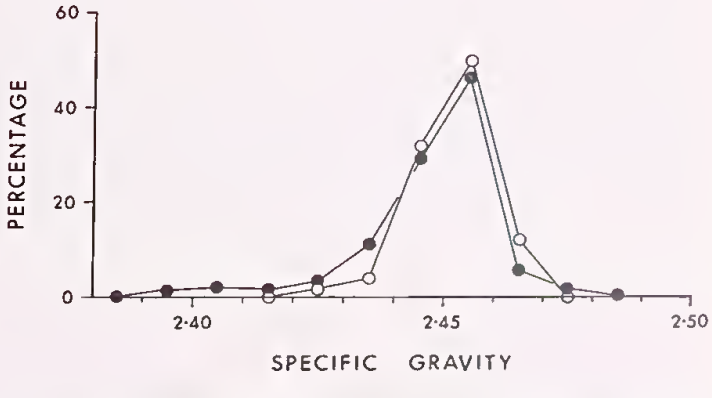

Figure 4 Frequency diagrams of specific gravity for australites. Open circles: sample of 50 australites from the vicinity of Kambalda. Filled circles: sample of 268 australites from the Kalgoorlie area from Chapman *et al.* (1964, Fig. 3).

Figure 5 Australites from the Eastern Goldfields, Western Australia, natural size except where otherwise stated. In side or end views, direction of flight is towards bottom of page. A Typical australites from Goongarrie showing abraded forms. B Round core, side view showing lack of defined rim, Goongarrie, x 1.2. C Severely abraded, square-ended aberrant form, anterior surface showing faint remnants of longitudinal flow ridges, Goongarrie, x 1.2. D Lens with remnants of butt of flange, anterior surface showing flow ridge unusually well preserved for Goongarrie area, x 1.2. E Round core, anterior surface with etched V-grooves, Goongarrie, x 1.2. F Fragment of elongated indicator II with remnant of stress shell on one end, Goongarrie. G Round indicator I, posterior surface, lake country NW of Kalgoorlie. H Broad oval canoe, side view, Seven Mile Hill area, x 1.5. K Vesicular fragment, D2.409, Seven Mile Hill area, x 2. L Round core, posterior surface above with etch pattern, side view below with rectangular flake scars, Seven Mile Hill area. M Seed type aberrant form, anterior surface with flow ridges, Seven Mile Hill area, x 1.5. N Elongate fragment, anterior surface above with flow ridges, side view below with turned up flange in middle of front face, Seven Mile Hill area, x 1.5. O Flanged broad oval, posterior surface, elongation 1.04, Kambalda area. P Fragment of elongated lens-form with pronounced sawcut, Kambalda area, x 1.5. Q Teardrop-indicator II, side view, Kambalda area. R Boat-core, posterior surface above, side view below, end view below right, Kambalda area. S Boat-indicator II, posterior view. Spalling has occurred from this surface. Kambalda area. T Narrow oval indicator II, side view showing small remnants of stress shell at each end, Kambalda area, x 1.5. U Small round core, side view showing numerous narrow parallel flake scars, Kambalda area.

mple 2 An area centred 20 km NW of Kalgoorlie ains several tens of closely crowded, usually dry lake ns and clay pans with intervening gypseous dunes. local name for such terrain is "lake country" (Fig. 1). 616 australites in the sample are from 6 parcels, each result of searching dry basins and their approaches 2). Some of the smaller lakes or parts of lakes have graphic protection. A few australites of the less ist types have therefore survived (Fig. 5G).

he morphology of Sample 2 from the lake country ple 1, col 2), with one notable exception, is rather ilar to that of the sample from the extensive lake em on Hampton Hill Station (Cleverly 1986). Thus, the sifiable percentage (item 6) is a 50.3% (Hampton Hill ion 49.8%) and the percentage of round forms (item 7) 8.5% (cf. 66%). The exception is in items 15 and 18, ing a cores/lens-forms ratio of 0.30 in contrast with for the Hampton Hill sample. Cores range up to large , but lens-forms are derived from flanged forms of ited thickness (Cleverly 1988b). A low cores/lens-ns ratio suggests that the mean weight of whole cimens will also be low. Thus, for Sample 2, the mean ight is 1.71 g (item 21), but for Hampton Hill Station it .08 g (Cleverly 1986). Table 1, items 19 and 21 show the gular increase of mean weight from 1.62 g at the ratio to 3.67 g at ratio 0.89. Although there are several wn exceptions to this general trend in samples from ewhere, this is because the ratio depends, *inter alia*, on quality of the sample. For example, a carelessly lected sample tends to contain an unduly high propor-n of the larger (core type) specimens and thus to have a sleadingly high cores/lens-forms ratio and high mean ight.

A frequency diagram of specific gravity for 50 austral-s from Sample 2 (Fig. 3) is unimodal with 41 of the ues in the 2.44-2.46 range and no values exceeding 2.47. e diagram matches closely the one for a sample of 59 stralites from Broad Arrow and Gindalbie (Chapman *et* 1964, Fig. 3), a typical "normal australite" diagram.

Sample 3 Seven Mile Hill is 12 km SW of Kalgoorlie ride Great Eastern Highway (Fig. 1). The sample of 299 stralites was gathered from 2-3 km SE of the hill below e low lateritic plateau known locally as Afghan Rocks, which there is a group of gnamma holes (Honman 14, Pl. III). Drainage is to the eastern end of a belt of ake country", distinctly separate from that of Sample 2.

Much of Sample 3 was collected further from the lakes an the other samples. Sample 3 contains a number of all and fragile forms, and thus has a rather high mber of shape types for a sample of this size (Table 1, l 3). Details of several of the small specimens, with an count of the role of folding in their development, have en given by Cleverly (1979). The fragile forms include a oken pineseed described by Cleverly (1982).

Afghan Rocks gnamma holes was an aboriginal occupa-on site which has been searched for the presence of stralite artifacts (Cleverly and Cleverly 1985). Flakes of alcedony and other fine-grained siliceous materials are esent on the gentle rise overlooking the gnamma holes, t no australite flakes were found. The sample in the llotson collections from the breakaways and ground below the plateau contains a single australite flake. Destructive use of australites by aborigines was evidently minimal in this area. The likely reasons are a lack of large australites (only two in the sample weigh more than 10 g each), and/or the ready availability of a variety of usable, fine-grained siliceous rocks.

A frequency diagram of specific gravity for 275 australites from Seven Mile Hill in the Tillotson collections (Chapman 1971, Fig. 4(d)) is part of a figure illustrating "normal australites and normal philippinites" in Chapman's chemical classification.

Sample 4 The first Kambalda township, on an angular promontory jutting into Lake Lefroy 55 km SSE of Kalgoorlie, was dependent on gold mining for its existence. Australites were well known in the principal alluvial patch at the lake edge south of the township, and were highly regarded by local propectors as indicators of good gold values (G Cleverly *pers comm*). This belief was once held in other goldfields also (Baker 1959). The modern Kambalda East, a more extensive town in the same general area as the first town, is concerned with nickel and gold mining. Kambalda West is a dormitory town centred 4 km WSW of Kambalda East (Fig. 1).

The australite sample was gathered from two general areas:

(a) The low-lying ground extending from Kambalda West down to Lake Lefroy and along the margin of the lake (106 specimens).

(b) About 6 km N of Kambalda East in the bed of a large creek which flows SE into an angular embayment of the lake (75 specimens); also from the alluvial fan and lake in that vicinity (63 specimens).

Samples of 25 specimens from each of areas (a) and (b) have mean specific gravity and standard deviation 2.453±0.006 and 2.450±0.008 respectively. They have been accepted as parts of the same population. A frequency diagram of specific gravity for the combined samples (Fig. 4) is unimodal with 82% of the values between 2.44 and 2.46, and no values exceeding 2.47. The diagram matches closely the one for 268 specimens from the Kalgoorlie area (Chapman *et al* 1964, Fig. 3), a typical "normal australite" diagram.

Part of Sample 4 is from the flats south of Kambalda West, which are vegetated and have very little slope. The other part is from an area north of Kambalda East, where erosive forces are severe. It was possible to unite the two parts of the sample for a study of specific gravity, but their morphology (Table 1, col 4) would preferably have been considered as two separate units if specimen numbers had not been so small. As examples, the 50.4% of essentially complete australites (item 2) is made up of 57.5% for the western part of the sample and only 44.9% for the northern part: the 61.9% classifiable specimens (item 6) consists of 66.9% and 57.9% for the respective parts: the mean weight of 3.67 g for whole specimens (item 21) comprises 4.36 g for the western and 3.00 g for the northern parts of the sample. All of these differences are consistent with the greatly different environments of the western and northern parts of the sample area.

Discussion and conclusions

The four australite samples were collected by the same people within the one geographic and climatic region, and all are of the same chemical type. It is possible that the morphology of the australite shower varied little from place to place in the Eastern Goldfields, because the considerable differences now existing between samples may be largely understood by differences in the intensity of the weathering and erosion processes to which they have been subjected since arrival on the earth's surface. In particular, the degree of exposure to the open, salt lake situation, where erosion processes are severe, is a major factor.

A possible exception to uniformity in the shower was a difference in the sizes of the primary bodies from place to place. The development of flanged forms, and hence of lens-forms (amongst others), is limited to primary bodies of thickness less than c 40 mm (Cleverly 1988b). Because cores formed aerodynamically do not have that upper size limit, the original size differences may now show up in the cores/lens-forms ratio.

Factors other than weathering and erosion affect the nature of australite samples gathered elsewhere or by other people. In the well-vegetated south-west of Western Australia, australites are much more difficult to detect than on the bare ground and lake basins of the Eastern Goldfields. For example, 49 australites from the farm of F Davis east of Yealering, centred 32°37'S, 117°56'E, have mean weight 17.6 g and cores/lens-forms ratio 8.0. These figures contrast with the average values for the four samples discussed in this study, which are 1.59 g and 0.44. Careless or casual collection has much the same effect on the nature of the sample as obscuring vegetation. There are also places such as the Nullarbor Plain where human usage of australites has affected the nature of the samples, not only in the abundance of australite artifacts, but in the rarity or absence of the larger usable australites (Cleverly 1976, Table 1).

The study of further australite locality samples from outside the Eastern Goldfields is desirable before making firm decisions on these tentative conclusions.

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